Visualization of Cavitation-induced Dynamic Fracture in Soft Adhesives

Yamaguchi, T.; Koike, K.; Doi, M.

Visualization of Cavitation-induced Dynamic Fracture in Soft Adhesives

JST/CREST, Dept.of Applied Physics, Univ.of Tokyo T.Yamaguchi [1], K.Koike, and M.Doi

粘着剤は、弱く架橋されたエラストマーであり、低い弾性率と高い粘性を持つ。粘着剤を基板から引離すとき、粘着剤-基板界面にキャビティと呼ばれる空孔が発生することが観察されているが、これまでの実験では基板に垂直な方向からの観察しか行なわれていなかったため、キャビティの立体形状や、キャビテーションと界面破壊過程との関連はよく分かっていなかった。そこで我々は、粘着剤中のキャビティを立体観察する方法を開発し、実際に引離し過程を観察したところ、粘着剤の弾性率とキャビティ立体形状、応力-歪み曲線（破壊エネルギー）が互いに密接な関連を持っていることが明らかとなった。

1 Introduction

When we evaluate the stickiness of soft adhesives, the probe-tack test is often used. In this test, a flat-ended probe is indented onto an adhesive thin film which is coated on a glass substrate, kept contact for a given time, and pulled out with constant speed, then the stress-strain curve is obtained. Creton and co-workers [1] studied nucleation and growth of cavities inside the adhesive with an optical microscope, and they mentioned cavitation has a great influence on the stress-strain curves. Here a question arises: what is the stereoscopic shape of cavities? In the previous experiments, however, observations were done only in the direction normal to the film, and the 3D information of the internal structure has not been obtained yet. Here we developped a simple technique to visualize the 3D structure in the adhesive thin film by in-situ experiments, and observed growth kinetics of cavities in samples with various elastic modulus.

2 Experiment

Our experimental aparatus is schematically illustrated in Figure 1(a). The adhesive samples used were Acrylic solution type (Soken Chemical and Engineering), and 3 types of adhesive sample were prepared by changing the cross-linking density (×1: standard sample, ×10, and ×30). The film thickness was $287 \pm 15\mu m$. From rheological measurements (Physica MCR301, Anton Paar), we confirmed the equillibrium elastic modulus was roughly proportional to the cross-linking density. The probe-tack testing was performed with a tensile testing machine (MST-1,

[1]E-mail: yamaguchi@rheo.t.u-tokyo.ac.jp

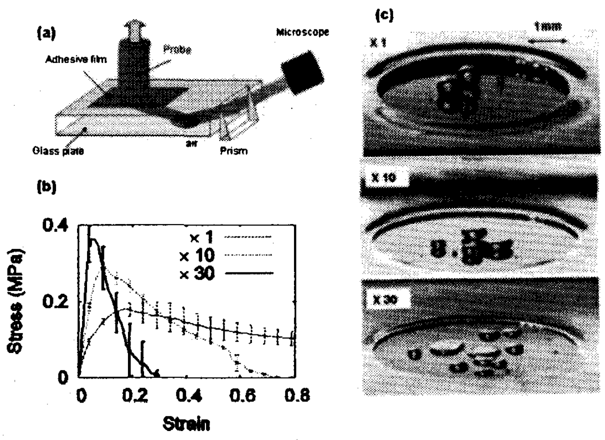

Figure 1: (a) Experimental apparatus (b) Stress-strain curve for the 3 samples. (c) Snapshots of the debonding process.

Shimadzu) and a glass plate ($\phi = 5mm$, Sigma Koki) was used as a probe. The separation speed was $10\mu m/s$.The stress and the strain were calculated by Force/Nominal contact area and Displacement/Initial film thickness, respectively. The probe-tack tests were also recorded with a digital microscope (VHX-200/100F, Keyence) by 60 magnifications.

3 Results and Discussion

The stress-strain curves are shown in Figure 1(b) for the 3 samples. The stress-strain curve showed a distinct peak and an abrupt drop, followed by the plateau region and the final fall to zero stress for the standard sample. On the other hand, for samples with larger cross-linking density (ie., larger elastic modulus), the debonding stress dropped to zero without the plateau region. Moreover, a snapshot in each sample is shown in Figure 1(c). For the standard sample, spherical cavities nucleate and expanded without coalescing with each other, but the behaviour greatly changed as we increased cross-linking density: cavities become flatter and tend to coalesce easily.

Acknowledgment

We thank Prof.C.Creton, Prof.Y.Masubuchi, Dr.T.Saito for helpful discussions and experimental supports. This work is supported by JST/CREST.

References

[1] K. R. Shull and C. Creton, J.Polym.Sci.B **42** (2004), 4023